CH 3 POWER (WORK RATE) EXAMPLE

An electrical motor has 2.5 kW of electrical input and it rejects heat at a rate of 35 Btu/min.
What is the power output of this engine in horsepower [hp]?
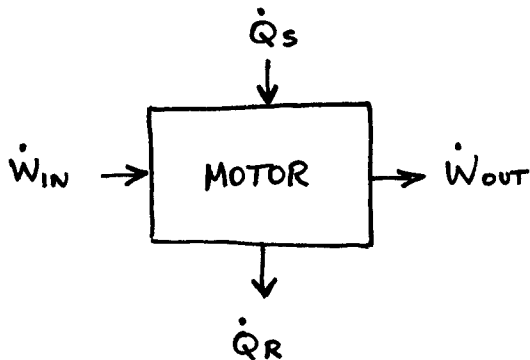
"POWER" IS THE RATE OF WORK.

IF WORK IS DENOTED BY W [FT LBf], THEN THE RATE OF WORK IS:

$$\dot{W} \left[\frac{FT \ LBf}{MIN} \right] \equiv POWER$$

POWER AND WORK ARE RELATED THROUGH MASS FLOW RATE, $\dot{m} \left[\frac{LBm}{MIN} \right]$.

$$\dot{W} \left[\frac{FT \ LBf}{MIN} \right] = \dot{m} \left[\frac{LBm}{MIN} \right] \times w \left[\frac{FT \ LBf}{LBm} \right]$$

* SEE YOUR EQUATION SHEET FOR EQUIVALENT UNITS OF POWER
(e.g. HP, kW, etc.)

FIRST LAW OF THERMODYNAMICS:

$$\Sigma W = \Sigma Q$$

SO, EQUIVALENT IS:

$$\Sigma \dot{W} = \Sigma \dot{Q}$$

IN THIS PROBLEM: $\dot{W}_{IN} = -2.5 \ kW$ $\dot{Q}_S = 0$ (NO INFO GIVEN)

$\dot{W}_{OUT} = ?$ $\dot{Q}_R = -35 \ \frac{Btu}{MIN}$ ("HOW IN")

SO:

$$\dot{W}_{IN} + \dot{W}_{OUT} = \dot{Q}_S + \dot{Q}_R$$

$$-2.5 \ kW + \dot{W}_{OUT} = 0 + \left(-35 \ \frac{Btu}{MIN} \right)$$

$$\dot{W}_{OUT} = 2.5 \ kW \left(\frac{1 \ HP}{.746 \ kW} \right) + \left(-35 \ \frac{Btu}{MIN} \right) \left(\frac{1 \ HP}{42.42 \ \frac{Btu}{MIN}} \right)$$

$$= 3.35 \ HP + (-.83 \ HP)$$

$$\boxed{\dot{W}_{OUT} = 2.52 \ HP}$$

↳ POWER OUTPUT OF THE MOTOR

STEADY FLOW ENERGY EQUATION (SFEE) EXAMPLE

15 Btu/lb$_m$ of heat is supplied to a steady flow system, in which the working fluid remains at constant velocity. The outlet height is 77.8 ft above the inlet. Inlet and outlet properties are as follows:

① INLET
p = 5760 lb$_f$/ft^2
v = 15 ft^3/lb$_m$
u = 300 Btu/lb$_m$

② OUTLET
p = 6480 lb$_f$/ft^2
v = 10 ft^3/lb$_m$
u = 225 Btu/lb$_m$

ALSO FROM ABOVE:

$q_{12} = +15 \frac{Btu}{LBm}$
(USING "HOW IN")

FROM ABOVE STATEMENT
$\begin{cases} Z = 0 \text{ FT} & Z = 77.8 \text{ FT} \\ V_1 = V_2 \text{ (VELOCITY)} & V_2 = V_1 \text{ (VELOCITY)} \end{cases}$

a) Is this an OPEN or CLOSED system?

OPEN SYSTEM — SFEE APPLIES TO OPEN SYSTEM

b) Calculate work [Btu/lb$_m$] done by or on system. Indicate if this is WORK IN or WORK OUT of the system.

APPLY SFEE TO FIND WORK W_{12} [Btu/LBm]:

$$pe_1 + Ke_1 + fw_1 + u_1 + q_{12} = pe_2 + Ke_2 + fw_2 + u_2 + W_{12}$$

$$\cancel{Z_1}\left(\frac{g}{g_c}\right) + \frac{1}{2g_c}\cancel{(V_1)^2} + p_1v_1 + u_1 + q_{12} = Z_2\left(\frac{g}{g_c}\right) + \frac{1}{2g_c}\cancel{(V_2)^2} + p_2v_2 + u_2 + W_{12}$$

REARRANGE:

$$W_{12} = -Z_2\left(\frac{g}{g_c}\right) + \left(p_1v_1 - p_2v_2\right) + \left(u_1 - u_2\right) + q_{12}$$

$$= -77.8 \text{ FT}\left(\frac{LBf}{LBm}\right) + \left[\left(5760\frac{LBf}{FT^2}\right)\left(15\frac{FT^3}{LBm}\right) - \left(6480\frac{LBf}{FT^2}\right)\left(10\frac{FT^3}{LBm}\right)\right] +$$

$$\left(300\frac{Btu}{LBm} - 225\frac{Btu}{LBm}\right) + 15\frac{Btu}{LBm}$$

$$= -77.8\frac{FT\ LBf}{LBm}\left(\frac{1\ Btu}{778\ FT LBf}\right) + \left(21,600\frac{FT\ LBf}{LBm}\right)\left(\frac{1\ Btu}{778\ FT LBf}\right) +$$

$$75\frac{Btu}{LBm} + 15\frac{Btu}{LBm}$$

$$= -.1\frac{Btu}{LBm} + 27.8\frac{Btu}{LBm} + 75\frac{Btu}{LBm} + 15\frac{Btu}{LBm}$$

$$\boxed{W_{12} = +117.7\frac{Btu}{LBm}}$$

↳ WORK OUT (USING "HOW IN")